Sensitivity of optimal gains in a detached boundary layer

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The flow over a 2D bump at moderate Reynolds numbers[1,2] is studied as a prototype of detached boundary layers. It is well known that such non-normal systems can exhibit large energy amplification even in their stable regime, as characterized by transient growth in the time domain or by optimal gain in the frequency domain.

This study characterizes optimal gains in the bump flow in the stable regime, $Re < 590$. These optimal gains reach very large values in a range of frequencies close to those of least stable eigenmodes. Their variation with Re is depicted in Figure 1. Corresponding optimal forcings are mainly located close to the summit of the bump, whereas optimal responses are located further downstream.

Next, regions where steady forcing in the domain or blowing at the wall leads to greatest increase or decrease of the optimal gains are identified, as illustrated in Figure 2. These regions of maximum sensitivity are determined using a Lagrangian formalism[3] and validated against full simulations. This sensitivity information is useful to design an efficient open-loop control aiming at reducing noise amplification in this flow.

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[1]Marquillie and Ehrenstein, *J. Fluid Mech.* **490**, 169 (2003).

[2]Ehrenstein and Gallaire, *J. Fluid Mech.* **614**, 315 (2008).

[3]Brandt et al., *J. Fluid Mech.* **687**, 503 (2011).

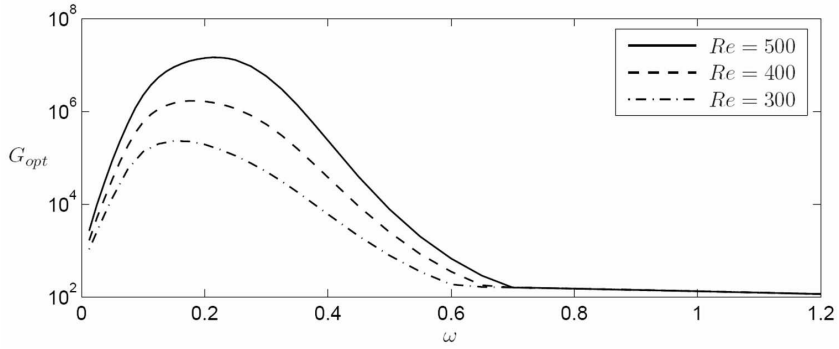

Figure 1: Optimal gain $G_{opt}(\omega)$ at $Re = 300, 400, 500$.

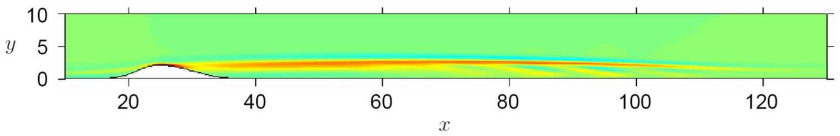

Figure 2: Sensitivity of the optimal gain to steady forcing in the bulk, $Re = 500$, $\omega = 0.23$.